

**Test Report:
Total Ionizing Dose Testing of
JANS2N3501 Silicon NPN Transistor**

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1. Introduction

This report describes the response to total ionizing dose radiation of the JANS2N3501 NPN silicon bipolar transistor manufactured by Microsemi Corp.

2. Procedure

Five parts were tested. There was one control device. The parts were exposed to gamma rays emanating from the NASA/GSFC Co⁶⁰ cell at a dose rate of 20 mrad(Si)/s without any applied electrical bias. Parametric values were measured prior to the first exposure and then immediately following each incremental dose.

3. Part Information

Table I.
2N3501 Device and Test Information

Part Number:	JANS2N3501
Manufacturer:	Semicoa
Lot Date Code (LDC):	0002
Quantity to be Tested:	5
Serial Numbers of Control Sample:	5
Serial Numbers of Radiation Samples:	1, 2, 3, 4
Part Function:	Transistor
Part Technology:	Bipolar
Package Style:	TO-39
Test Equipment:	Parametric Analyzer, dual power supply
Test Engineer:	J. Forney
Dose Levels (krad (Si))	0, 5, 10, 15, 20, 30 and 40
Target dose rate (rad (Si)/sec)	0.02

4. Test Setup for Measuring Parametric Values

The collector of the transistor was biased at 10 V and the emitter was grounded. Voltage (V_A) was applied to the transistor's base connection through a 1 k Ω resistor. V_A was scanned from 0 V to 11.1 V in steps of 0.1 V. Base current (I_b) and collector current (I_c) were measured at each step. V_{eb} was calculated from $V_B - 1000 \cdot I_b$.

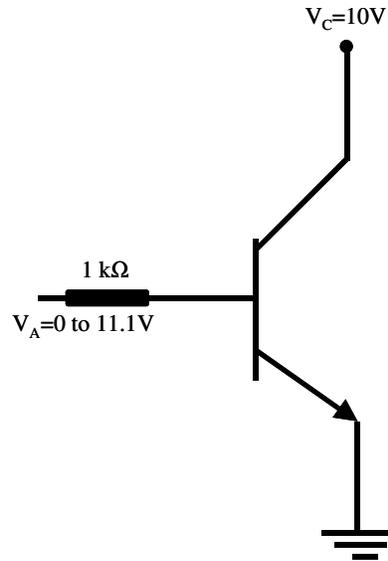


Fig. 1. Bias conditions for testing the 2N3501 transistor.

5. Results

The following parametric values were monitored as a function of ionizing dose:

- Forward-Current Transfer Ratio
- Collector-Emitter Saturation Voltage
- Base-Emitter Voltage

a) Forward-Current Transfer Ratio

CTR was measured for the following four conditions:

$I_c=0.1 \text{ mA}$, $V_{cd}=10V$

$I_c=1.0 \text{ mA}$, $V_{ce}=10V$

$I_c=10.0 \text{ mA}$, $V_{ce}=10V$

$I_c=80.0 \text{ mA}$, $V_{ce}=10V$

(The data sheet specifies a measurement at $I_c=150 \text{ mA}$. This could not be done because of excessive power dissipation. Therefore, we opted to do the measurement at 80 mA.)

Table II
Forward-CTR as a Function of Dose for $I_c=0.1$ mA and $V_{ce}=10V$.

	DUT#1	DUT#2	DUT#3	DUT#4	Control	Average	St. Dev.	Spec
0	169	174	160	178	NA	170.25	7.76	>35
5	143	152	141	151	NA	146.75	5.56	>35
10	121	129	124	129	152	125.75	3.95	>35
15	89	115	109	103	152	104.00	11.14	>35
20	80	95	69	78	124	80.50	10.79	>35
30	76	81	83	78	145	79.50	3.11	>35
40	67	69	71	69	NA	69.00	1.63	>35

Table III
Forward-CTR as a Function of Dose for $I_c=1.0$ mA and $V_{ce}=10V$.

	DUT#1	DUT#2	DUT#3	DUT#4	Control	Average	St. Dev.	Spec
0	184	188	171	192	NA	183.75	9.11	>50
5	161	168	155	168	NA	163.00	6.27	>50
10	146	152	142	152	164	148.00	4.90	>50
15	134	141	131	139	165	136.25	4.57	>50
20	125	130	134	132	152	130.25	3.86	>50
30	109	111	110	112	163	110.50	1.29	>50
40	100	102	100	113	NA	103.75	6.24	>50

Table IV
Forward-CTR as a Function of Dose for $I_c=10$ mA and $V_{ce}=10V$.

	DUT#1	DUT#2	DUT#3	DUT#4	Control	Average	St. Dev.	Spec
0	200	202	182	206	NA	197.50	10.63	>75
5	185	189	173	190	NA	184.25	7.80	>75
10	170	174	161	175	180	170.00	6.38	>75
15	162	166	153	166	180	161.75	6.13	>75
20	152	156	144	156	179	152.00	5.66	>75
30	142	142	135	144	179	140.75	3.95	>75
40	133	134	126	133	NA	131.50	3.70	>75

Table V
Forward-CTR as a Function of Dose for $I_c=80$ mA and $V_{ce}=10V$.

	DUT#1	DUT#2	DUT#3	DUT#4	Control	Average	St. Dev.	Spec
0	242	242	246	246	NA	244.00	2.31	NA
5	230	232	212	234	NA	227.00	10.13	NA
10	210	212	195	214	212	207.75	8.66	NA
15	203	204	188	206	212	200.25	8.26	NA
20	197	200	185	200	215	195.50	7.14	NA
30	187	186	174	189	214	184.00	6.78	NA
40	178	177	166	169	NA	172.50	5.92	NA

The results above show that all the part starts are within specifications for forward-CTR up to 40 krad(Si).

b) Base-Emitter Saturation Voltage

Table IX
V_{be} (measured with I_c=150 mA and I_b=10 mA.)

	DUT#1	DUT#2	DUT#3	DUT#4	Control	Average	St. Dev.	Spec
0	0.7	0.7	0.7	0.7	0.7	0.70	0.00	>0.6
5	0.7	0.7	0.7	0.7	0.7	0.70	0.00	>0.6
10	0.7	0.7	0.7	0.7	0.7	0.70	0.00	>0.6
15	0.7	0.7	0.7	0.7	0.7	0.70	0.00	>0.6
20	0.7	0.7	0.6	0.7	0.7	0.68	0.05	>0.6
30	0.6	0.7	0.7	0.7	0.7	0.68	0.05	>0.6
40	0.6	0.7	0.6	0.7	0.7	0.65	0.06	>0.6

The data shows that V_{be} meets specifications up to the maximum total dose of 40 krad(Si).

c) Collector-Emitter Saturation Voltage

Table X
V_{ce} (Measured with I_c=150 mA and I_b=5 mA)

	DUT#1	DUT#2	DUT#3	DUT#4	Control	Average	St. Dev.	Spec
0	0.123	0.114	0.123	0.117	NA	0.12	0.00	NA
5	0.129	0.128	0.129	0.129	NA	0.13	0.00	NA
10	0.128	0.13	0.13	0.128	0.13	0.13	0.00	NA
15	0.135	0.133	0.12	0.135	0.135	0.13	0.01	NA
20	0.138	0.142	0.146	0.143	0.161	0.14	0.00	NA
30	0.138	0.135	0.142	0.142	0.14	0.14	0.00	NA
40	0.14	0.131	0.139	0.139	NA	0.14	0.00	NA

6. Conclusions

The four parts tested passed all tests up to a total dose of 40 krad(Si).